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## Analysis of Free Electron Laser Performance Utilizing the National Bureau of Standards' CW Microtron

CHA-MEI TANG AND PHILLIP SPRANGLE

*Plasma Physics Division*

SAMUEL PENNER

*Center for Radiation Research  
National Bureau of Standards  
Gaithersburg, MD 20899*

XAVIER K. MARUYAMA

*Department of Physics  
Naval Postgraduate School  
Monterey, CA 93940*

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19 ABSTRACT (Continue on reverse if necessary and identify by block number) The National Bureau of Standards' (NBS) CW racetrack microtron (RTM) will be utilized as a driver for a free electron laser (FEL) oscillator. The NBS RTM possesses many exceptional properties of value for the FEL: i) CW operation, ii) energy from 20-185 MeV, iii) small energy spread and emittance, iv) excellent energy stability, and v) high average power. The 1-D FEL gain formula predicts that the FEL would oscillate at the fundamental approximately from 0.25 $\mu\text{m}$ to 10 $\mu\text{m}$ when up-grading the peak current to $\geq 2\text{A}$ . In this paper, we present 3-D self-consistent numerical results including several realistic effects, such as emittance, betatron oscillations, diffraction and refraction. The results indicate that the design value of the transverse emittance is small enough that it does not degrade the FEL performance for intermediate to long wavelengths, and only slightly degrades the performance at the shortest wavelength under consideration. Due to the good emittance, the current density is high enough that focusing, or guiding, beings to manifest itself for wavelengths $> 2.0 \mu\text{m}$ .					
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# Analysis of Free Electron Laser Performance Utilizing the National Bureau of Standards' CW Microtron

## Introduction

An FEL facility for applications, primarily in biomedical and material science research as well as for basic physics and chemistry, is to be situated at the National Bureau of Standards<sup>1,2</sup>. A CW 185 MeV racetrack microtron (RTM)<sup>3</sup> is under construction. The NBS Accelerator Laboratory consists of a series of interconnected, individually shielded, underground halls. The updated layout is indicated in Fig. 1. The FEL is expected to be operational by 1990.

The major limitation of an RTM as an FEL driver is that its peak current capability is lower than electron linacs which operate in the same energy range. However, the RTM is superior to pulsed linacs in energy spread and emittance. The RTM is comparable to a storage ring in terms of beam emittance and energy spread, but there is no restriction on insertion length or "stay clear" aperture. The beam energy can be varied continuously over a wide range without significant loss of performance. In addition, microtrons are compact and energy efficient. Because of the CW nature of the RTM, the generation of coherent photons is not hindered by a finite macropulse length.

The original design parameters of the NBS RTM are given in Refs. 1-3. The design calculations indicate a longitudinal emittance  $\epsilon_L < 30$  keV-degrees and a normalized transverse emittance<sup>1,2</sup>  $\epsilon_N < 10$  mm-mrad. Based on recent measurements of the performance of the 5 MeV injector linac, the actual values of both the longitudinal and transverse emittance are expected to be smaller than the design values. The injector system must be upgraded to provide a peak current of  $\geq 2$  A in 3.5 psec micropulses, giving electron pulse length  $\ell_{eb} \simeq 0.1$  cm. In order to keep the average electron beam power within the capability of the existing RF power system, the new injector will fill only a small fraction of the RF buckets (e.g., 1/24, 1/120 depending on electron beam energy). We are proceeding with a design of a photocathode injector system for this upgrade.

## 1-D Free Electron Laser Analysis

A first order evaluation of the FEL performance of the NBS RTM can be obtained from the 1-D small signal low gain formula<sup>4</sup>. The results indicate that sufficient gain can

be obtained at fundamental wavelengths in the range from  $10 \mu m > \lambda > 0.25 \mu m$ . The formula for the electric field amplitude gain  $G$  in the small signal, low gain regime, can be written as

$$G = F_1^2 \frac{\pi^2}{\sigma_R} \frac{I}{I_A} \frac{\lambda_w^2}{\gamma_o^3} K^2 N^3 \frac{\partial}{\partial \nu} \left( \frac{\sin \nu}{\nu} \right)^2,$$

where  $N$  is the number of wiggler periods,  $\gamma_o$  is the initial relativistic gamma factor,  $\sigma_R = \pi r_o^2$  is the cross-sectional area of the radiation,  $r_o$  is the minimum  $1/e$  radius of the Gaussian radiation field amplitude,  $I_A = 17 \times 10^3$  A,  $I$  is the current in Amperes,  $K = (|e|B_w \lambda_w / 2\pi m_o c^2)_{RMS}$  is the wiggler parameter,  $B_w$  is the magnetic field in the wiggler,  $\lambda_w$  is the wavelength of the wiggler,  $F_1 = J_0(b) - J_1(b)$  for a linearly polarized wiggler,  $b = K^2/2(1+K^2)$ ,  $\nu = -N\lambda(\omega - \omega_o)/2c$  is the normalized frequency mismatch, and  $\omega_o \sim 2\gamma^2 c(2\pi/\lambda_w)/(1+K^2)$  is the resonant angular frequency. The function  $\partial/\partial \nu(\sin \nu/\nu)^2$  has a maximum value of 0.54 when  $\nu = -1.3$ .

The power gain can be obtained by

$$G_p = (1 + G)^2 - 1.$$

In the low gain regime,  $G_p \simeq 2G$ . The FEL will oscillate when the power gain is greater than the losses per pass in the resonator. The 1-D gain formula is only a rough estimate. It is sensitive to the choice of filling factor.

The conceptual design consists of a linearly polarized wiggler with a period of  $\lambda_w = 2.8$  cm, and a nominal magnetic field amplitude of  $B_{wo} = 5400$  G. This can be constructed with a hybrid wiggler design with the gap separating the wiggler poles of  $g = 1.0$  cm. A wiggler can be constructed conceptually in more than one section, such that a wiggler of shorter length can also be available. A shorter wiggler and a corresponding vacuum chamber may be necessary for long wavelength operation.

Figure 2 is a plot of the 1-D maximum small signal power gain versus wavelength, assuming a conservative peak current of 2 A. The open circles (o) are obtained with electron beam energies of 25, 50, 75, 125, and 175 MeV. The solid curves are obtained for the same electron beam energies, but varying the wiggler amplitude from  $0.6B_{wo}$  to  $B_{wo}$ . The magnetic field in the wiggler is to be changed by varying the gap between the poles

from 1.4 cm to 1.0 cm. As the magnetic field decreases, the wavelength of the radiation decreases, and the gain is reduced.

### 3-D Effects on the Gain

Since FELs are not actually 1-D, 3-D effects will change the gain. Some of the 3-D effects that we will examine in this paper are finite transverse emittance, radiation diffraction and refraction, and some effects associated with finite-length electron pulses.

We will assess these three-dimensional effects using a fully 3-D self-consistent computer code, SHERA, developed at the Naval Research Laboratory. The formulation of the wave equation is based on the source dependent expansion<sup>5</sup> of the radiation field, and the electron dynamics<sup>6</sup> are evaluated self-consistently. We assume a waterbag distribution in the 4-D transverse emittance space, which leads to a parabolic profile for the electron beam density. Since the energy spread of the NBS RTM is very small, it will not be considered; and we will also not treat the effects of pulse slippage on the gain. The radiations are taken to have a Rayleigh length of 175 cm with the minimum radiation waist located at the center of the wiggler. Results for two different operating regimes will be presented.

The effect of the emittance on the performance of the FEL will be more important for short wavelength operations. Thus, our first example will be for  $\lambda = 0.23 \mu\text{m}$  with  $\gamma_o = 350$ . The pulse slippage distance,  $N\lambda = 0.003 \text{ cm}$ , is much shorter than the electron pulse length,  $\ell_{eb}$ . The minimum  $1/e$  radiation field amplitude waist is  $r_o = 3.57 \times 10^{-2} \text{ cm}$ . Plots of the power gain,  $G_p$ , versus the normalized frequency mismatch,  $\nu$ , are shown in Figure 3. Curve (a) gives the 1-D estimate of the gain. Curves (b), (c) and (d) are the gains calculated from the computer code for normalized transverse emittance of  $\epsilon_N = 5, 10$  and  $20 \text{ mm mrad}$ , respectively. The radii of the electron beams were determined by properly matching the beam into the wiggler, i.e., the radii of the beams inside the wiggler is uniform. The matched beam radius condition is

$$r_{eb} = \left( \frac{\epsilon_N}{\gamma K_\beta} \right)^{1/2}$$

where  $K_\beta = \sqrt{2\pi K/\lambda_w \gamma}$  is the betatron wavenumber for wiggler with parabolic pole faces<sup>7</sup>, where the focusing in both transverse directions is equal. The matched edge radius of the

electron beam can be rewritten as

$$r_{eb} = \left( \frac{\lambda_w \epsilon_N}{\sqrt{2\pi K}} \right)^{1/2},$$

independent of the beam energy. The matched edge radii of the electron beam are  $r_{eb} = 1.77 \times 10^{-2}$ ,  $2.50 \times 10^{-2}$  and  $3.54 \times 10^{-2}$  cm for normalized edge transverse emittances of  $\epsilon_N = 5$ , 10 and 20 mm mrad, respectively. If the emittance becomes larger than 20 mm mrad, the radius of the electron beam will become larger than the radiation spot size, and the gain will be substantially reduced.

The effect of finite emittance on the gain is negligible for  $\lambda = 1.25 \mu\text{m}$  with  $\gamma_o = 150$ . The pulse slippage distance in this case is 0.016 cm, and it is still unimportant. Figure 4 shows plots of the power gain,  $G_p$ , versus the normalized frequency mismatch,  $\nu$ , similar to Fig. 3. Again, the curve (a) gives the 1-D estimate of gain. Curves (b), (c) and (d) are the gains calculated from the computer code for normalized emittance of  $\epsilon_N = 5$ , 10 and 20 mm mrad, respectively. Since the wavelength is longer, the minimum  $1/e$  radiation field amplitude waist becomes  $r_o = 8.3 \times 10^{-2}$  cm, and the electron beam radii are much smaller than the radiation waist. The gain at  $\lambda = 1.25 \mu\text{m}$  is insensitive to the design value of the finite transverse emittance.

Figures 3 and 4 also show a shift of the zero crossing of the gain curves obtained from 3-D simulation. This shift comes from the change in the phase of the diffracting radiation field. It has no real important effect on the oscillation criteria for the examples under consideration.

Figure 5 plots the maximum 3-D power gain versus wavelength with a peak current of 2 A, for normalized emittances of 5, 10, and 20 mm mrad. Each curve is obtained for the identified electron beam energy, but varying the magnetic wiggler amplitude from  $B_{wo}$  to  $0.6B_{wo}$ , where the longer wavelength correspond to the larger magnetic field. Normalized emittance is very good in the long wavelength operating regime. In the shortest wavelength operating regime, the normalized emittance larger than 5 mm mrad should be avoided.

Since the current is a function of axial position in a finite length electron pulse, and pulse slippage is unimportant, the local gain is a function of the local current in the electron

pulse. For the first example at  $\lambda = 0.23 \mu\text{m}$  with normalized transverse edge emittance  $\epsilon_N = 10 \text{ mm mrad}$ , the simulations indicate that the gain is proportional to the local current, consistent with the 1-D formula. For the second example at  $\lambda = 1.25 \mu\text{m}$ , the gain increases faster than the linear power of the current. Figure 6 is a plot of normalized power gain, i.e., power gain from simulation divided by the maximum 1-D power gain, versus the frequency mismatch at  $\lambda = 1.25 \mu\text{m}$  with normalized transverse edge emittance  $\epsilon_N = 10 \text{ mm mrad}$  for three different currents: (a)  $I = 4.0 \text{ A}$ , (b)  $I = 2.0 \text{ A}$  and (c)  $I = 0.5 \text{ A}$ . We find that the normalized gain increases as current increases. This can be explained by the self-focusing or guiding phenomenon<sup>5,8-11</sup> of the FEL. This is most easily observed in the plots of the normalized  $1/e$  Gaussian radiation field amplitude radius, shown in Fig. 7. For  $I = 0.5 \text{ A}$ , the radiation radius behaves like a free space resonator radiation field, curve (- - -). For  $I = 2 \text{ A}$ , the radiation radius is less than the free space radius at the end of the wiggler as self-focusing begins to show, curve (—). If the current can be increased to  $4 \text{ A}$ , the radiation becomes even more focused, curve (.....). The reason that self-focusing is evident at such low current is that the emittance is very good and current density is high throughout the interaction region, i.e., high beam brightness  $B_N = 2I/(\pi^2 \epsilon_N^2) > 4 \times 10^9 \text{ A/m}^2/\text{rad}^2$ , where  $I > 2 \text{ A}$  and edge emittance  $\epsilon_N = 10 \text{ mm mrad}$ .

### Conclusions

The 3-D self-consistent simulation results from the computer code SHERA indicate that the design value of the transverse emittance is very good, so that it does not degrade the FEL performance for intermediate to long wavelengths. For the shortest wavelength under consideration, emittance larger than  $5 \text{ mm mrad}$  should be avoided. Due to the good emittance, the current density is high enough that focusing, or guiding, begins to manifest itself for wavelengths  $> 2.0 \mu\text{m}$ .

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## References

- [1] C.M. Tang, P. Sprangle, S. Penner, B.M. Kincaid and R.R. Freeman, Nucl. Instr. and Meth. A250, 278 (1986). Also in: Free Electron Lasers, Proc. 7th Int. Conf. on FELs, eds., E.T. Scharlemann and D. Prosnitz (North-Holland, Amsterdam, 1986) p. 278.
- [2] X.K. Maruyama and S. Penner, C.M. Tang and P. Sprangle, Free Electron Lasers, Proc. of the 8th Intl. FEL Conf., ed., M. W. Poole (North-Holland, Amsterdam, 1987) p. 259.
- [3] S. Penner et al., IEEE Trans. Nucl. Sci. NS-32, 2669 (1985).
- [4] P. Sprangle, R.A. Smith and V.L. Granatstein, Infrared Millimeter Waves, Vol. I, ed., K.J. Button (Academic Press, New York, 1979) p. 279.
- [5] P. Sprangle, A. Ting and C.M. Tang, Phys. Rev. Lett. 59, 202 (1987), P. Sprangle, A. Ting and C.M. Tang, Phys. Rev. A36, (1987), and P. Sprangle, A. Ting and C. M. Tang, Free Electron Lasers, Proc. of the 8th Intl. FEL Conf., eds., M. W. Poole (North-Holland, Amsterdam, 1987) p. 136.
- [6] C.M. Tang and P. Sprangle, IEEE J. of Quantum Elec. QE-21, 970 (1985).
- [7] E. T. Scharlemann, J. Appl. Phys., 58, 2154 (1985).
- [8] P. Sprangle and C.M. Tang, Appl. Phys. Lett. 39, 677 (1981). Also in: C.M. Tang and P. Sprangle, Free-Electron Generator of Coherent Radiation, Physics of Quantum Electronics, Vol. 9, eds., S.F. Jacobs, G.T. Moore, H.S. Pilloff, M. Sargent III, M.O. Scully, R. Spitzer (Eddison-Wesley, Reading, MA, 1982) p. 627.
- [9] E.T. Scharlemann, A.M. Sessler and J.S. Wurtele, Phys. Rev. Lett. 54, 1925 (1985).
- [10] G.T. Moore, Opt. Comm. 52, 46(11084), 54, 121 (1985).
- [11] M. Xie and D.A.G. Deacon, same as ref. 1, p. 426.

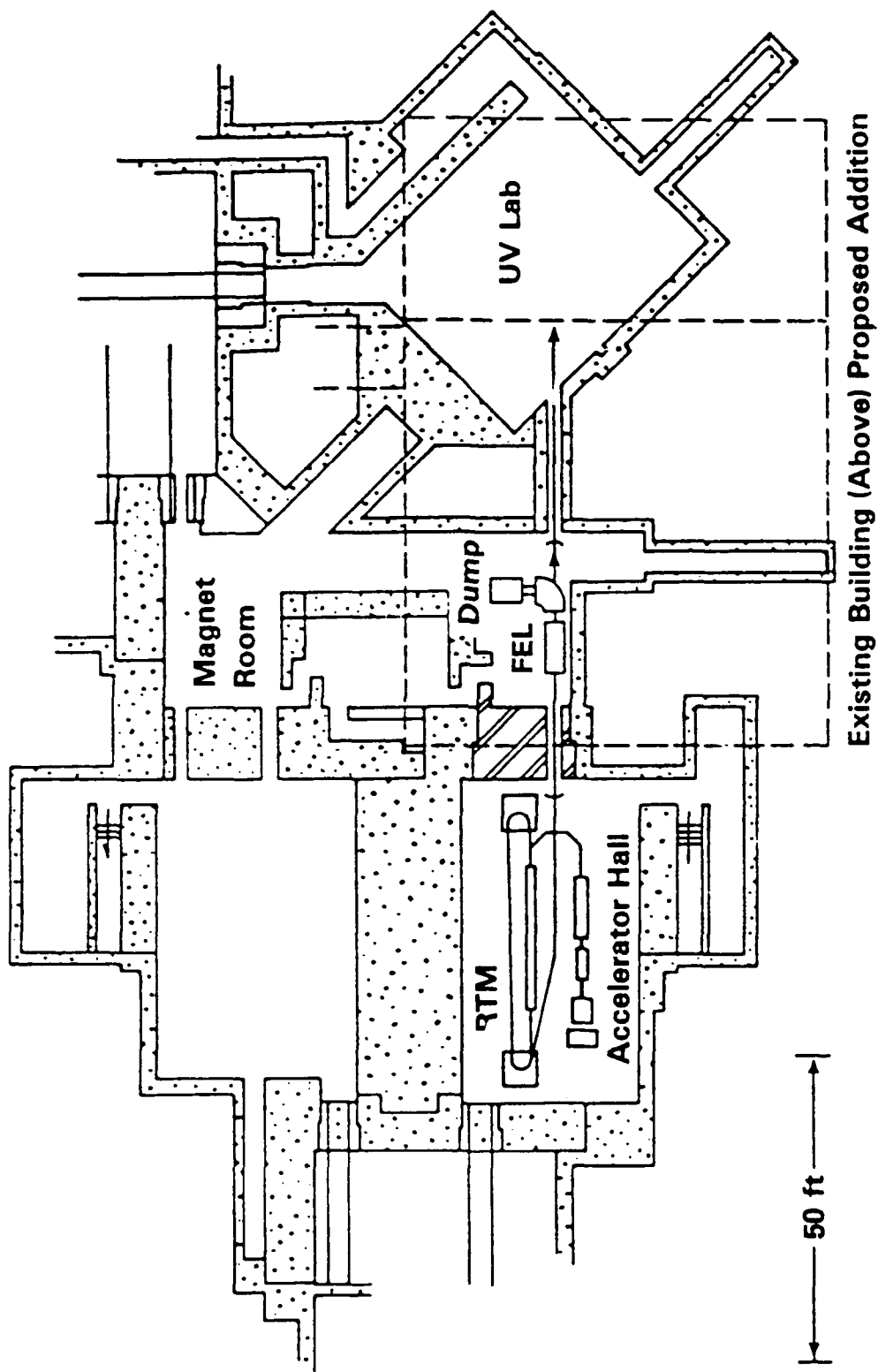
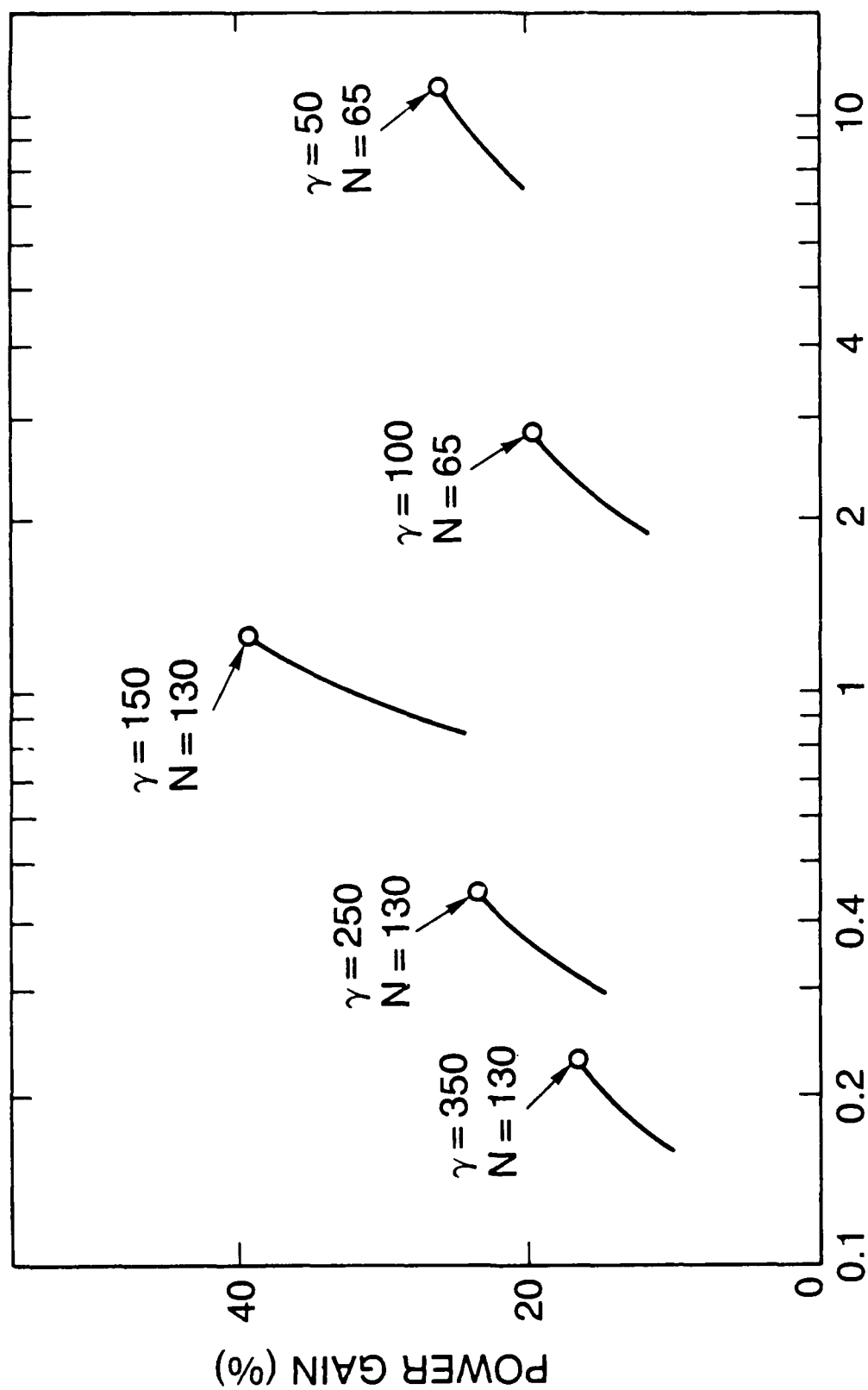


Fig. 1. Updated configuration for accelerator and FEL halls. The entire shielded complex is located 40 ft below ground level. Visible and infrared radiation will be directed to a ground level laboratory (indicated by the dashed lines) above the UV laboratory.



RADIATION WAVELENGTH,  $\lambda$  ( $\mu\text{m}$ )

Fig. 2. Small signal power gain versus wavelength based on 1-D calculation.

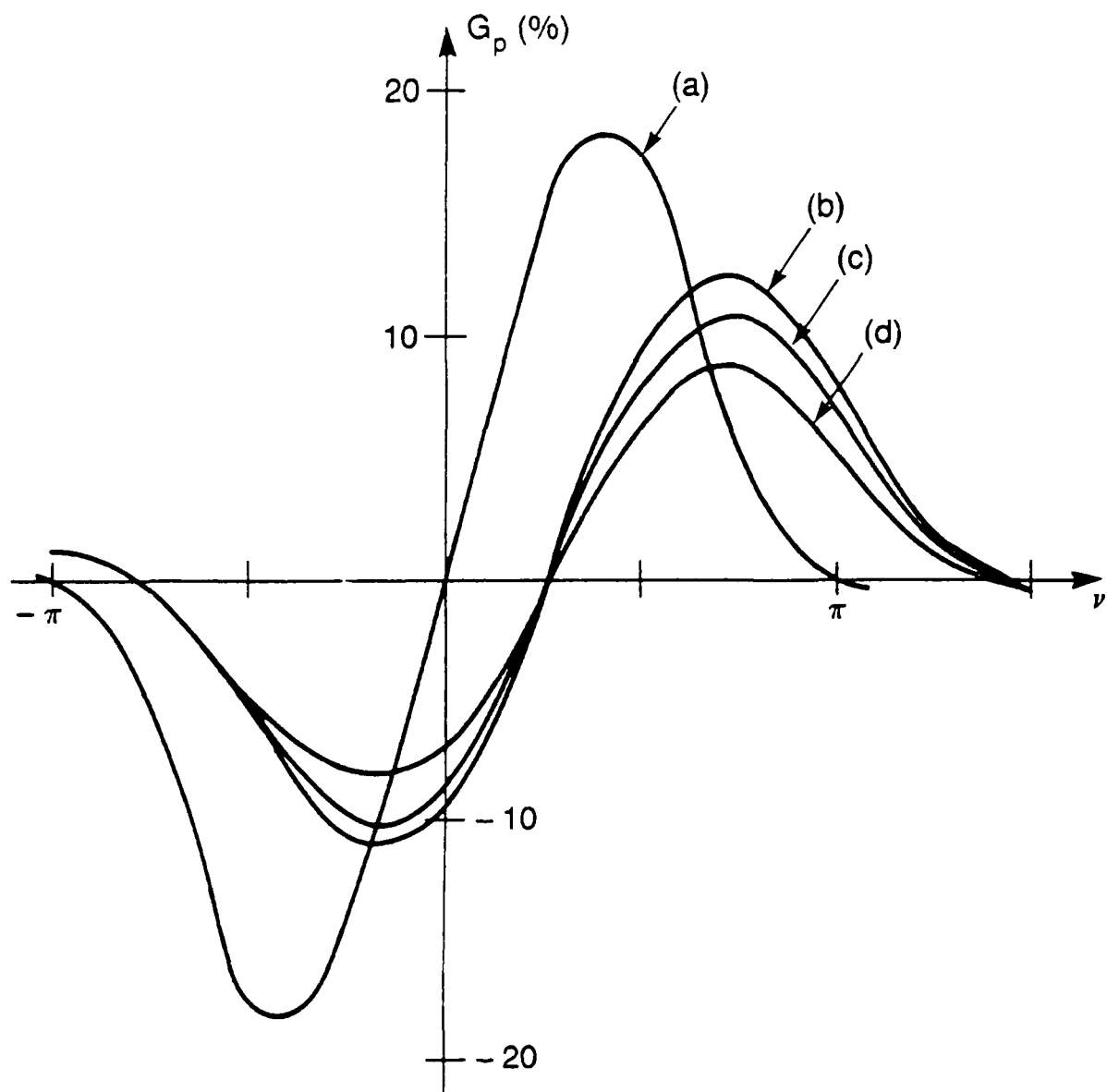


Fig. 3. Power gain,  $G_p$ , versus frequency mismatch,  $\nu$ , at  $\lambda = 0.23 \mu\text{m}$  with  $\gamma_o = 350$ . Curve (a) is based on 1-D gain formula. Curves (b), (c) and (d) are obtained from simulations with normalized transverse edge emittances of  $\epsilon_N = 5, 10$  and  $20 \text{ mm mrad}$ , respectively.

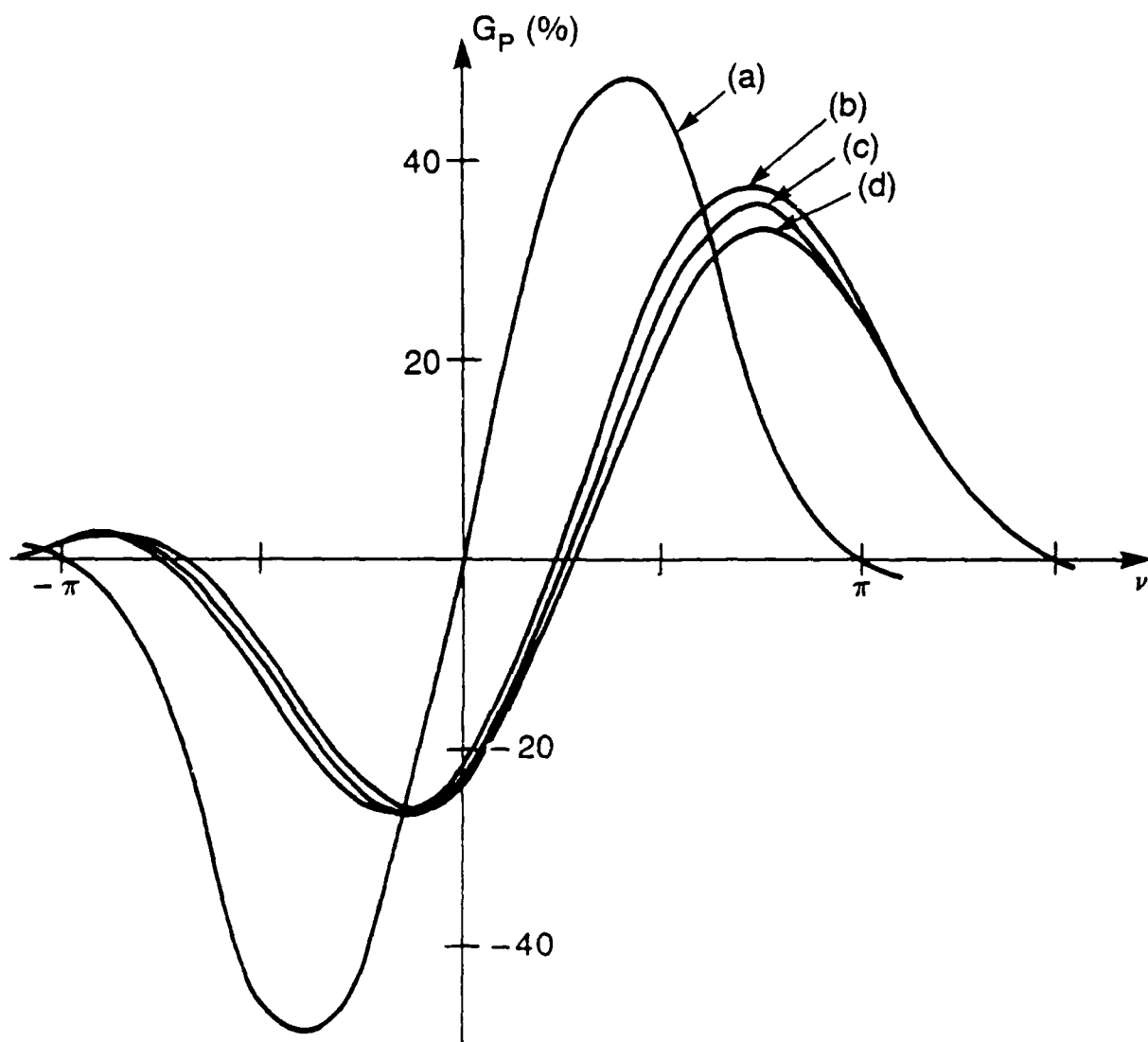


Fig. 4. Power gain,  $G_p$ , versus frequency mismatch,  $\nu$ , at  $\lambda = 1.25 \mu\text{m}$  with  $\gamma_o = 150$ . Curve (a) is based on 1-D gain formula. Curves (b), (c) and (d) are obtained from simulations with normalized transverse edge emittances of  $\epsilon_N = 5, 10$  and  $20 \text{ mm mrad}$ , respectively.

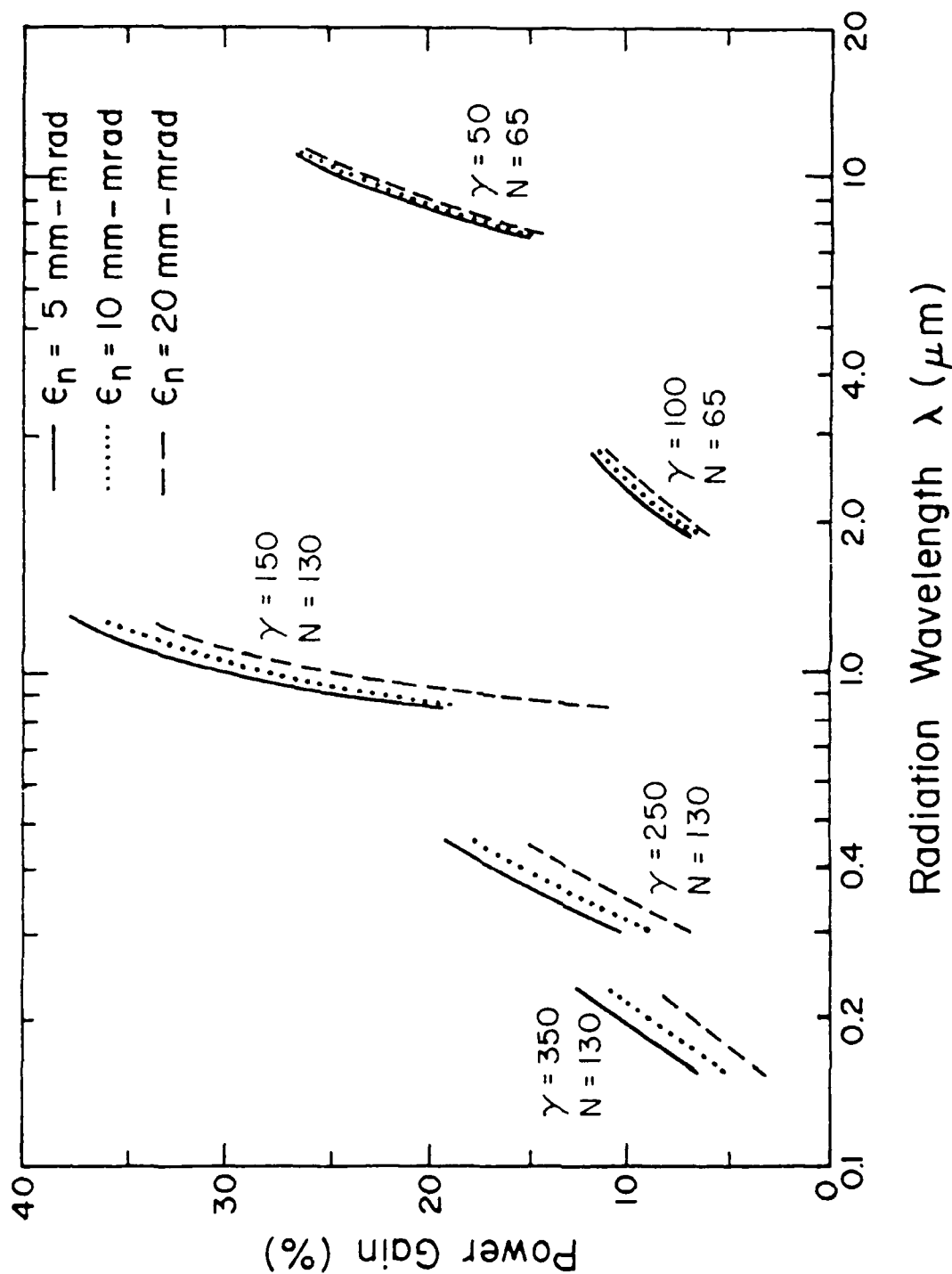


Fig. 5. Power gain versus wavelength based on a fully 3-D self-consistent simulation by varying energy and emittance of the electron beam, and the magnetic field of the wiggler.

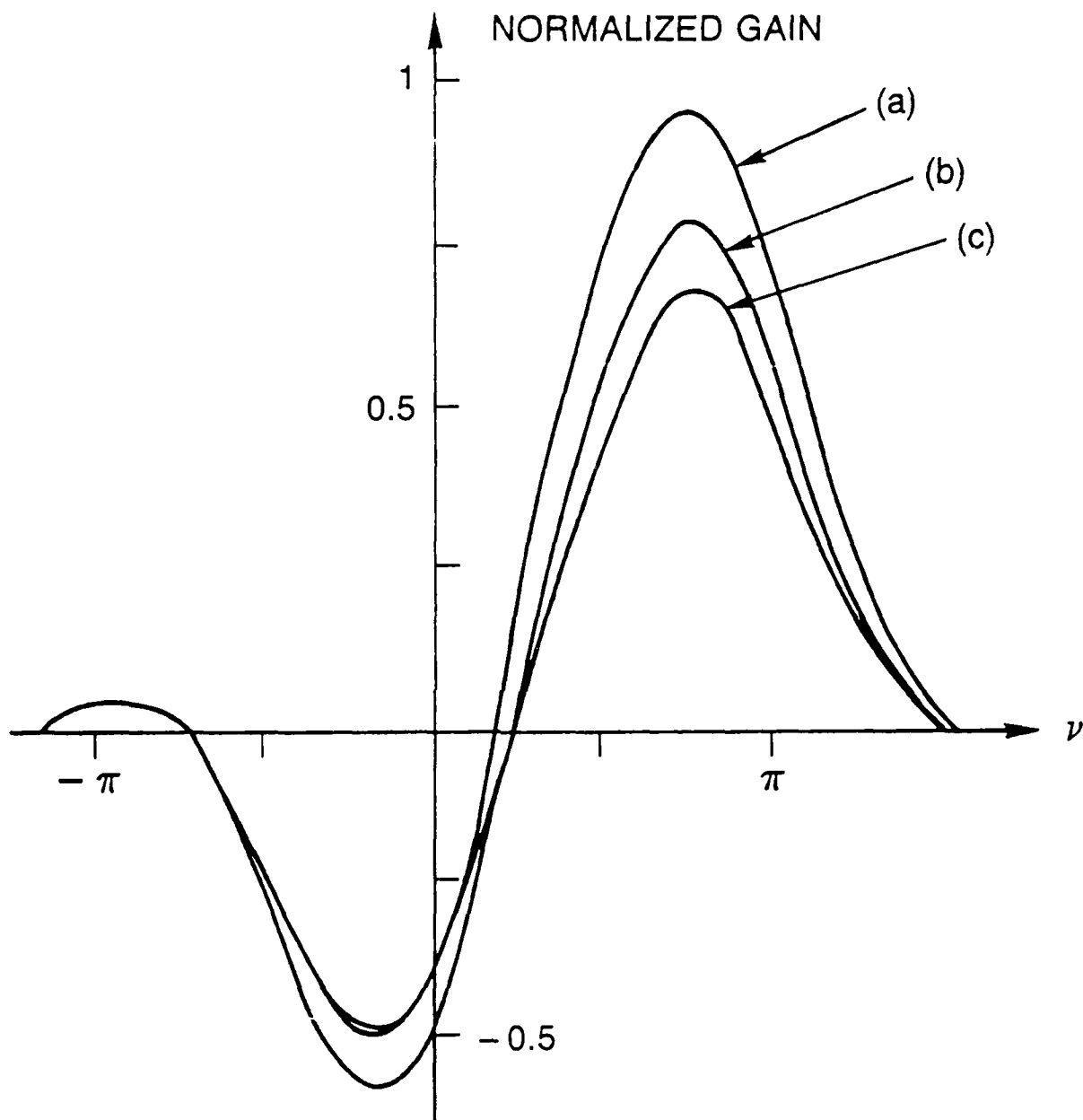


Fig. 6. Normalized gain versus frequency mismatch for  $\lambda = 1.26 \mu\text{m}$  and edge enittance of  $\epsilon_N = 10 \text{ mm mrad}$ . Curves (a), (b) and (c) correspond to results obtained with currents of  $I = 4.0, 2.0$ , and  $0.5 \text{ A}$ , respectively.

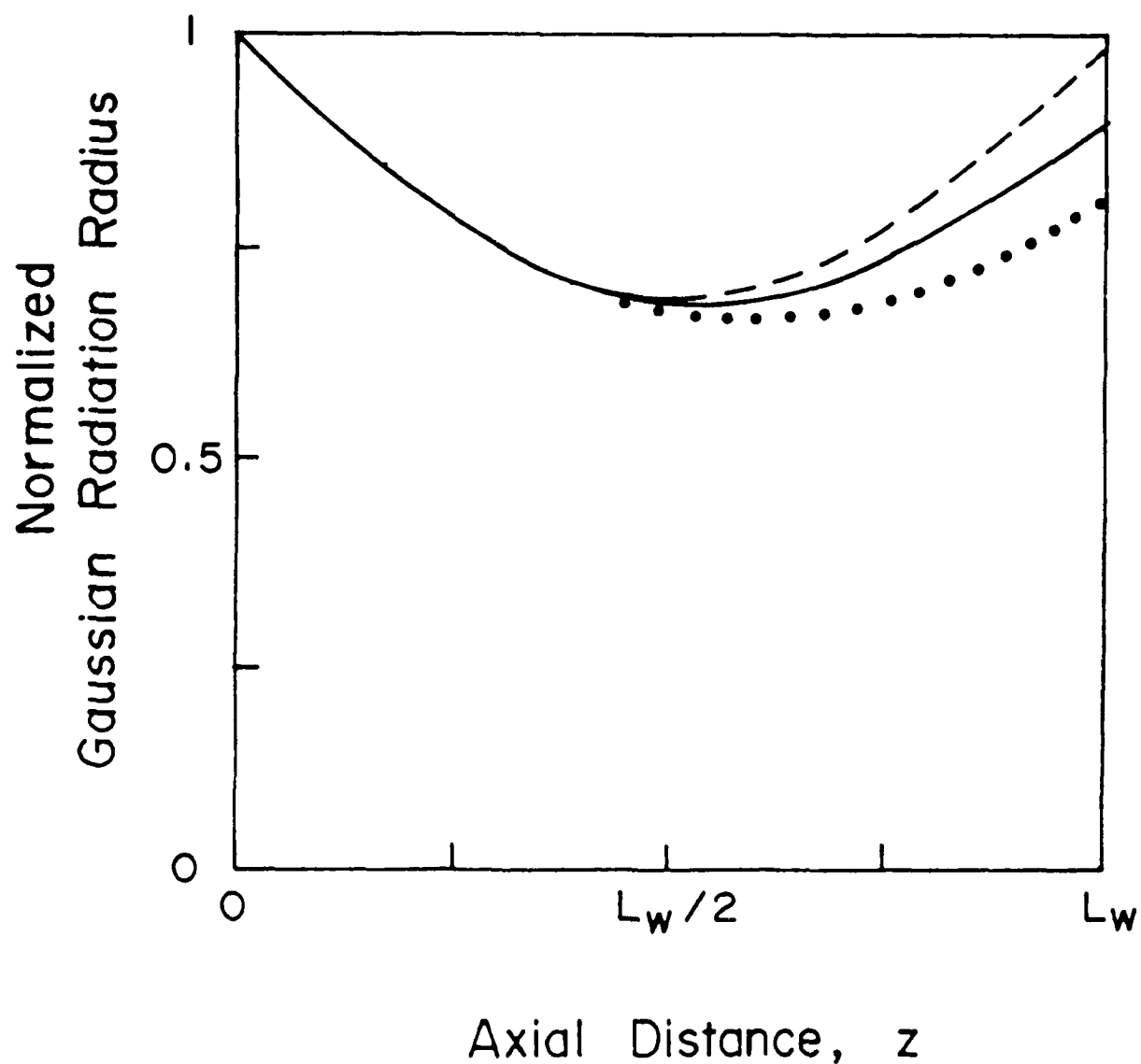


Fig. 7. Normalized  $1/e$  Gaussian radiation field amplitude radius as a function of distance  $z$  in the wiggler with  $\lambda = 1.25 \mu\text{m}$  and edge emittance  $\epsilon_N \approx 10 \text{ mm mrad}$  for three different currents: (---)  $I = 0.5 \text{ A}$ , (—)  $I = 2 \text{ A}$  and (.....)  $I = 4 \text{ A}$ .

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P. O. Box 808  
Livermore, CA 94550

Dr. J. Bisognano  
Lawrence Berkeley Laboratory  
University of California, Berkeley  
Berkeley, CA 94720

Dr. Steve Bitterly  
Rockwell International/Rocketdyne Div.  
6633 Canoga Avenue, FA-40  
Canoga Park, CA 91304

Dr. H. Boehmer  
TRW DSSG  
One Space Park  
Redondo Beach, CA 90278

Dr. P. Bosco  
KMS Fusion Inc.  
Ann Arbor, MI 48106

Dr. I. Boscolo  
Quantum Institute  
University of California  
Santa Barbara, CA 93106

Dr. B. Boswell  
Lab for Laser Energetics  
University of Rochester  
250 E. River Road  
Rochester, NY 14623

Dr. G. Bourianoff  
1901 Rutland Drive  
Austin, TX 78758

Dr. J. K. Boyd  
Lawrence Livermore National Laboratory  
P. O. Box 808  
Livermore, CA 94550

Dr. H. Brandt  
Department of the Army  
Harry Diamond Laboratory  
2800 Powder Mill Rd.  
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Dr. Charles Brau (2 copies)  
Los Alamos National Laboratory  
P.O. Box 1663, M.S. - 817  
Los Alamos, NM 87545

Dr. R. Briggs  
Lawrence Livermore National Lab.  
Attn: (L-71)  
P.O. Box 808  
Livermore, CA 94550

Dr. D. L. Bullock  
Optical Sciences Department  
TRW Space and Technology Group  
Redondo Beach, CA 90278

Dr. Fred Burskirk  
Physics Department  
Naval Postgraduate School  
Monterey, CA 93940

Dr. Ken Busby  
Mission Research Corporation  
1720 Randolph Road, S.E.  
Albuquerque, NM 87106

Dr. K. J. Button  
Francis Bitter Natl. Magnet Lab.  
M. I. T. Branch, Box 72  
Cambridge, MA 02139-09C1

Dr. J. A. Byers  
Lawrence Livermore National Lab.  
Attn: (L-630)  
P. O. Box 808  
Livermore, CA 94550

Dr. Gregory Canavan  
Office of Inertial Fusion  
U.S. Dept. of Energy  
M.S. C404  
Washington, DC 20545

Dr. Malcolm Caplan  
4219 Garland Drive  
Fremont, CA 94536

Dr. Maria Caponi  
TRW, Building R-1, Room 1184  
One Space Park  
Redondo Beach, CA 90278

Dr. B. Carlsten  
Los Alamos National Laboratory  
P. O. Box 1663  
Los Alamos, NM 87545

Dr. A. Carmichael  
U. S. Army - FTC  
P. O. Box 1500  
Huntsville, AL 35807-3801

Dr. J. Cary  
University of Colorado  
Box 391  
Boulder, CO 80309

Dr. R. Center  
Math. Sci. NW., Inc.  
2755 Northup Way  
Bellevue, WA 98004

Prof. Frank Chan  
School of Eng. & Applied Sciences  
Univ. of Calif. at Los Angeles  
7731 K Boelter Hall  
Los Angeles, CA 90024

Dr. K. C. Chan  
Los Alamos National Laboratory  
P. O. Box 1663  
Los Alamos, NM 87545

Dr. V. S. Chan  
GA Technologies  
P.O. Box 85608  
San Diego, CA 92138

Dr. Will E. Chandler  
Pacific Missile Test Center  
Code 0141-5  
Point Muga, CA 93042

Dr. Wen Wei Chang  
Department of Physics  
Univ. of Calif. at Los Angeles  
Los Angeles, CA 90024

Dr. J. Chase  
Lawrence Livermore National Laboratory  
P. O. Box 808  
Livermore, CA 94550

Dr. S. Chattopadhyay  
Lawrence Berkeley Laboratory  
University of California, Berkeley  
Berkeley, CA 94720

Dr. S. Chen  
MIT Plasma Fusion Center  
NW16-176  
Cambridge, MA 01890

Dr. Yu-Juan Chen  
L-626  
Lawrence Livermore National Laboratory  
P. O. Box 808  
Livermore, CA 94550

Dr. D. P. Chernin  
Science Applications Intl. Corp.  
1720 Goodridge Drive  
McLean, VA 22102 \*

Dr. Art Chester  
Hughes E51  
Mail Stop A269  
P.O. Box 902  
El Segundo, CA 90245

Dr. Abraham Chian  
IGPD  
Univ. of Calif. at Los Angeles  
Los Angeles, CA 90024

Dr. S. C. Chiu  
GA Technologies Inc.  
P.O. Box 85608  
San Diego, CA 92138

Dr. Y. C. Cho  
NASA-Lewis Research Center  
Mail Stop-54-5  
Cleveland, Ohio 44135

Dr. J. Christiansen  
Hughes Aircraft Co.  
Electron Dynamics Division  
3100 West Lomita Blvd.  
Torrance, CA 90509

Dr. T. L. Churchill  
Spectra Technology, Inc.  
2755 Northup Way  
Bellevue, WA 98004

Major Bart Clare  
USASDC  
P. O. BOX 15280  
Arlington, VA 22215-0500

Dr. Melville Clark  
8 Richard Road  
Wayland, MA 01778

Dr. Robert Clark  
P.O. Box 1925  
Washington, D.C. 20013

Dr. David E. Cline  
The Inst. for Accelerator Physics  
Department of Physics  
University of Wisconsin-Madison  
Madison, WI 53706

Dr. Alan J. Cole  
TRW  
One Space Park  
Redondo Beach, CA 90278

Dr. William Colson  
Berkeley Research Asso.  
P. O. Box 241  
Berkeley, CA 94701

Dr. William Condell  
Office of Naval Research  
Attn: Code 421  
800 N. Quincy St.  
Arlington, VA 22217

Dr. Richard Cooper  
Los Alamos National Scientific  
Laboratory  
P.O. Box 1663  
Los Alamos, NM 87545

Dr. Robert S. Cooper  
Director, DARPA  
1400 Wilson Boulevard  
Arlington, VA 22209

Dr. M. Cornacchia  
Lawrence Berkeley Laboratory  
University of California, Berkeley  
Berkeley, CA 94720

Dr. R. A. Cover  
Rockwell International/Rocketdyne Div.  
6633 Canoga Avenue, FA-38  
Canoga Park, CA 91304

Dr. D. Crandall  
ER-55, GTN  
Department of Energy  
Washington, DC 20545

Dr. M. S. Curtin  
KMS Fusion, Inc.  
P.O. Box 1567  
Ann Arbor, MI 48106

Dr. Antonello Cutolo  
Research Associate  
Hansen Labs  
NEPL Annex  
Stanford University  
Stanford, CA 94305

Dr. Bruce Danly  
MIT  
NW16-174  
Cambridge, MA 02139

Dr. R. Davidson (5 copies)  
Plasma Fusion Center  
Mass. Institute of Tech.  
Cambridge, MA 02139

Dr. John Dawson (4 copies)  
Physics Department  
University of California  
Los Angeles, CA 90024

Dr. David A. G. Deacon  
Deacon Research  
Suite 203  
900 Welch Road  
Palo Alto, CA 94306

Dr. T. L. Deloney  
Dept. of Electrical Engineering  
Stanford University  
Stanford, CA 94305

Deputy Under Secretary of  
Defense for R&AT  
Room 3E114, The Pentagon  
Washington, D.C. 20301

Dr. I. H. Deutsch  
Dept. of Physics & Plasma Fusion Ctr.  
Mass. Institute of Technology  
Cambridge, MA 02139

Prof. P. Diament  
Dept. of Electrical Engineering  
Columbia University  
New York, NY 10027

Dr. N. Dionne  
Raytheon Company  
Microwave Power Tube Division  
Foundry Avenue  
Waltham, MA 02154

Director  
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U. S. Naval Academy  
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Dr. T. Doering  
Boeing Aerospace Company  
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Seattle, WA 98124

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Northrop Corporation  
Defense Systems Division  
600 Hicks Road  
Rolling Meadows, IL 60008

Dr. Franklin Dolezal  
Hughes Research Laboratory  
3011 Malibu Canyon Rd.  
Malibu, CA 90265

Dr. A. Drobot  
Science Applications Intl. Corp.  
1710 Goodridge Road  
McLean, VA 22102

Dr. Dwight Duston  
Strategic Defense Initiative Org.  
OSD/SDIO/IST  
Washington, DC 20301-7100

Dr. Joseph Eberly  
Physics Department  
Univ. of Rochester  
Rochester, NY 14627

Dr. J. N. Eckstein  
Hansen Lab. of Physics  
Stanford University  
Stanford, CA 94305

Dr. J. A. Edighoffer  
TRW, Bldg. R-1  
One Space Park  
Redondo Beach, CA 90278

Dr. O. C. Eldridge  
University of Wisconsin  
1500 Johnson Drive  
Madison, WI 53706

Dr. Luis R. Elias (2 copies)  
Quantum Institute  
University of California  
Santa Barbara, CA 93106

Dr. C. J. Elliott  
Los Alamos National Laboratory  
P. O. Box 1663  
Los Alamos, NM 87545

Dr. James Elliott  
X1-Division, M.S. 531  
Los Alamos Natl. Scientific Lab.  
P. O. Box 1663  
Los Alamos, NM 87545

Dr. A. England  
Oak Ridge National Laboratory  
P.O. Box Y  
Mail Stop 3  
Building 9201-2  
Oak Ridge, TN 37830

Dr. William M. Fairbank  
Phys. Dept. & High Energy  
Phys. Laboratory  
Stanford University  
Stanford, CA 94305

Dr. Anne-Marie Fauchet  
Brookhaven National Laboratories  
Associated Universities, Inc.  
Upton, L.I., NY 11973

Dr. J. Feinstein  
Dept. of Electrical Engineering  
Stanford University  
Stanford, CA 94305

Dr. Frank S. Felber  
11011 Torreyana Road  
San Diego, CA 92121

Dr. D. Feldman  
Los Alamos National Laboratory  
P. O. Box 1663  
Los Alamos, NM 87545

Dr. Renee B. Feldman  
Los Alamos National Laboratory  
P. O. Box 1663  
Los Alamos, NM 87545

Dr. L. A. Ferrari  
Queens College  
Department of Physics  
Flushing, NY 11367

Dr. C. Finfgeld  
ER-542, GTN  
Department of Energy  
Washington, DC 20545

Dr. A. S. Fisher  
Dept. of Electrical Engineering  
Stanford University  
Stanford, CA 94305

Dr. R. G. Fleig  
Hughes Research Laboratory  
3011 Malibu Canyon Road  
Malibu, CA 90265

Dr. H. Fleischmann  
Cornell University  
Ithaca, NY 14850

Dr. E. Fontana  
Dept. of Electrical Engineering  
Stanford University  
Stanford, CA 94305

Dr. Norwal Fortson  
University of Washington  
Department of Physics  
Seattle, WA 98195

Dr. Roger A. Freedman  
Quantum Institute  
University of California  
Santa Barbara, CA 93106

Dr. Lazar Friedland  
Dept. of Eng. & Appl. Science  
Yale University  
New Haven, CT 06520

Dr. A. Friedman  
National Synchrotron Light Source  
Brookhaven National Laboratory  
Upton, NY 11973

Dr. Walter Friez  
Air Force Avionics Laboratory  
AFWAL/AADM-1  
Wright/Paterson AFB, OH 45433

Dr. Shing F. Fung  
Code 696  
GSFC  
NASA  
Greenbelt, MD 20771

Dr. R. Gajewski  
Div. of Advanced Energy Projects  
U. S. Dept of Energy  
Washington, DC 20545

Dr. H. E. Gallagher  
Hughes Research Laboratory  
3011 Malibu Canyon Road  
Malibu, CA 90265

Dr. James J. Gallagher  
Georgia Tech. EES-EOD  
Baker Building  
Atlanta, GA 30332

Dr. W. J. Gallagher  
Boeing Aerospace Co.  
P. O. Box 3999  
Seattle, WA 98124

Dr. J. Gallardo  
Quantum Institute  
University of California  
Santa Barbara, CA 93106

Dr. E. P. Garate  
Dept. of Physics and Astronomy  
Dartmouth College  
Hanover, NH 03755

Dr. A. Garren  
Lawrence Berkeley Laboratory  
University of California, Berkeley  
Berkeley, CA 94720

Dr. Richard L. Garwin  
IBM, T. J. Watson Research Ctr.  
P.O. Box 218  
Yorktown Heights, NY 10598

Dr. J. Gea-Banacloche  
Dept. of Physics & Astronomy  
Univ. of New Mexico  
800 Yale Blvd. NE  
Albuquerque, NM 87131

DR. R. I. Gellert  
Spectra Technology  
2755 Northup Way  
Bellevue, WA 98004

Dr. T. V. George  
ER-531, GTN  
Department of Energy  
Washington, DC 20545

Dr. Edward T. Gerry, President  
W. J. Schafer Associates, Inc.  
1901 N. Fort Myer Drive  
Arlington, VA 22209

Dr. Roy Glauber  
Physics Department  
Harvard University  
Cambridge, MA 02138

Dr. B. B. Godfrey  
Mission Research Corporation  
1720 Randolph Road, S. E.  
Albuquerque, NM 87106

Dr. John C. Goldstein, X-1  
Los Alamos Natl. Scientific Lab.  
P.O. Box 1663  
Los Alamos, NM 87545

Dr. Yee Fu Goul  
Plasma Physics Lab., Rm 102  
S.W. Mudd  
Columbia University  
New York, NY 10027

Dr. A. Gover  
National Synchrotron Light Source  
Brookhaven National Laboratory  
Upton, NY 11973

Dr. C. Grabbe  
Department of Physics  
University of Iowa  
Iowa City, Iowa 52242

Dr. V. L. Granatstein  
Dept. of Electrical Engineering  
University of Maryland  
College Park, MD 20742

Dr. D. D. Gregoire  
Quantum Institute and Dept. of Physics  
University of California  
Santa Barbara, CA 93106

Dr. Y. Greenzweig  
Quantum Inst. and Dept. of Physics  
University of California  
Santa Barbara, CA 93106

Dr. Morgan K. Grover  
R&D Associates  
P. O. Box 9695  
4640 Admiralty Highway  
Marina Del Rey, CA 90291

Dr. A. H. Guenter  
Air Force Weapons Laboratory  
Kirtland AFB, NM 87117

Dr. K. Das Gupta  
Physics Department  
Texas Tech University  
Lubbock, TX 79409

Dr. Benjamin Haberman  
Associate Director, OSTP  
Room 476, Old Exe. Office Bldg.  
Washington, D.C. 20506

Dr. K. Halbach  
Lawrence Berkeley Laboratory  
University of California, Berkeley  
Berkeley, CA 94720

Dr. P. Hammerling  
La Jolla Institute  
P.O. Box 1434  
La Jolla, CA 92038

Dr. F. Hartemann  
Dept. of Physics and Research  
Laboratory of Electronics  
Mass. Inst. of Technology  
Cambridge, MA 02139

Dr. R. Harvey  
Hughes Research Laboratory  
3011 Malibu Canyon Road  
Malibu, CA 90265

Prof. Herman A Haus  
Mass. Institute of Technology  
Rm. 36-351  
Cambridge, MA 02139

Dr. S. Hawkins  
Lawrence Livermore National Laboratory  
P. O. Box 808  
Livermore, CA 94550

Dr. Rod Hiddleston  
KMS Fusion  
3621 South State Road  
P. O. Box 1567  
Ann Arbor, MI 48106

Dr. J. L. Hirshfield (2 copies)  
Yale University  
Mason Laboratory  
400 Temple Street  
New Haven, CT 06520

Dr. K. Hizanidis  
Physics Dept.  
University of Maryland  
College Park, MD 20742

Dr. A. H. Ho  
Dept. of Electrical Engineering  
Stanford University  
Stanford, CA 94305

Dr. Darwin Ho  
L-477  
Lawrence Livermore National Laboratory  
P. O. Box 808  
Livermore, CA 94550

Dr. J. Hoffman  
Sandia National Laboratories  
ORG. 1231, P.O. Box 5800  
Albuquerque, NM 87185

Dr. R. Hofland  
Aerospace Corp.  
P. O. Box 92957  
Los Angeles, CA 90009

Dr. Fred Hopf  
Optical Sciences Building, Room 602  
University of Arizona  
Tucson, AZ 85721

Dr. Heinrich Hora  
Iowa Laser Facility  
University of Iowa  
Iowa City, Iowa

Dr. J. Y. Hsu  
General Atomic  
San Diego, CA 92138

Dr. H. Hsuar  
Princeton Plasma Physics Lab.  
James Forrestal Campus  
P.O. Box 451  
Princeton, NJ 08544

Dr. James Hu  
Quantum Inst. and Phys. Dept.  
University of California  
Santa Barbara, CA 93106

Dr. Benjamin Hubberman  
Associate Director, OSTP  
Rm. 476, Old Executive Office Bldg.  
Washington, DC 20506

Dr. J. Hyman  
Hughes Research Laboratory  
3011 Malibu Canyon Road  
Malibu, CA 90265

Dr. H. Ishizuka  
University of California  
Department of Physics  
Irvine, CA 92717

Dr. A. Jackson  
Lawrence Berkeley Laboratory  
University of California, Berkeley  
Berkeley, CA 94720

Dr. S. F. Jacobs  
Optical Sciences Center  
University of Arizona  
Tucson, AZ 85721

Dr. Pravin C. Jain  
Asst. for Communications Tech.  
Defense Communications Agency  
Washington, DC 20305

Dr. E. T. Jaynes  
Physics Department  
Washington University  
St. Louis, MO 63130

Dr. B. Carol Johnson  
Ctr. for Radiation Research  
National Bureau of Standards  
Gaithersburg, MD 20899

Dr. Bernadette Johnson  
Lincoln Laboratory  
Lexington, MA 02173

Dr. Richard Johnson  
Physics International  
2700 Merced St.  
San Leandro, CA 94577

Dr. G. L. Johnston  
NW 16-232  
Mass. Institute of Tech.  
Cambridge, MA 02139

Dr. Shayne Johnston  
Physics Department  
Jackson State University  
Jackson, MS 39217

Dr. William Jones  
U. S. Army SDC  
P. O. Box 1500  
Huntsville, AL 35807-3801

Dr. R. A. Jong  
Lawrence Livermore National Laboratory  
P. O. Box 808/L626  
Livermore, CA 94550

Dr. Howard Jory (3 copies)  
Varian Associates, Bldg. 1  
611 Hansen Way  
Palo Alto, CA 94303

Dr. C. Joshi  
University of California  
Los Angeles, CA 90024  
Dr. Paul Kennedy  
Rockwell International/Rocketdyne Div.  
6633 Canoga Avenue, FA-40  
Canoga Park, CA 91304

Dr. R. Kennedy  
Boeing Aerospace Company  
P.O. Box 3999  
Seattle, WA 98124

Dr. K. J. Kim, MS-101  
Lawrence Berkeley Lab.  
Rm. 223, B-80  
Berkeley, CA 94720

Dr. I. Imel  
Quantum Institute  
University of California  
Santa Barbara, CA 93106

Dr. Brian Kincaid  
AT&T Bell Labs  
700 Mountain Ave.  
Murray Hill, NJ 07974

Dr. S. P. Kno  
Polytechnic Institute of NY  
Route 110  
Farmingdale, NY 11735

Dr. Xu Knogyi  
Room 36-285  
Mass. Institute of Technology  
Cambridge MA 02139

Dr. A. Kolb  
Maxwell Laboratories, Inc.  
8835 Balboa Avenue  
San Diego, CA 92123

Dr. Eugene Kopf  
Principal Deputy Assistant  
Secretary of the Air Force (RD&L)  
Room 4E964, The Pentagon  
Washington, D.C. 20330

Dr. P. Korn  
Maxwell Laboratories, Inc.  
8835 Balboa Avenue  
San Diego, CA 92123

Dr. S. Krinsky  
Nat. Synchrotron Light Source  
Brookhaven National Laboratory  
Upton, NY 11973

Prof. N. M. Kroll  
Department of Physics  
B-019, UCSD  
La Jolla, CA 92093

Dr. Thomas Kwan  
Los Alamos National Scientific  
Laboratory, MS608  
P. O. Box 1663  
Los Alamos, NM 87545

Dr. Jean Labacqz  
Stanford University  
SLAC  
Stanford, CA 94305

Dr. Ross H. Labbe  
Rockwell International/Rocketdyne Div.  
6633 Canoga Avenue, FA-40  
Canoga Park, CA 91304

Dr. Willis Lamb  
Optical Sciences Center  
University of Arizona  
Tucson, AZ 85721

Dr. H. Lancaster  
Lawrence Berkeley Laboratory  
University of California, Berkeley  
Berkeley, CA 94720

Dr. D. J. Larson  
The Inst. for Accelerator Physics  
Department of Physics  
University of Wisconsin-Madison  
Madison, WI 53706

Dr. J. LaSala  
Physics Dept.  
U. S. M. A.  
West Point, NY 10996

Dr. Bernard Laskowski  
M.S. 230-3  
NASA-Ames  
Moffett Field, CA 94305

Dr. Charles J. Lasnier  
TRW  
High Energy Physics Lab.  
Stanford University  
Stanford, CA 94305

Dr. Michael Lavan  
U.S. Army Strategic Def. Command  
ATTN: Code DASD-H-WD  
P. O. Box 1500  
Huntsville, AL 35807-3801

Dr. Ray Leadabrand  
SRI International  
333 Ravenswood Avenue  
Menlo Park, CA 94025

Dr. Kotik K. Lee  
Perkin-Elmer  
Optical Group  
100 Wooster Heights Road  
Danbury, CT 06810

Dr. K. Lee  
Los Alamos Nat. Scientific Lab.  
Attn: X-1 MS-E531  
P. O. Box 1663  
Los Alamos, NM 87545

Dr. Barry Leven  
NISC/Code 20  
4301 Suitland Road  
Washington, D.C. 20390

Dr. B. Levush  
University of Maryland  
College Park, MD 20742

Dr. Lewis Licht  
Department of Physics  
Box 4348  
U. of Illinois at Chicago Cir.  
Chicago, IL 60680

Dr. M. A. Lieberman  
Dept. EECS  
Univ. of Cal. at Berkeley  
Berkeley, CA 94720

Dr. Anthony T. Lin  
Dept. of Physics  
University of California  
Los Angeles, CA 90024

Dr. B. A. Lippmann  
Stanford Linear Accel. Center  
BIN 26  
Stanford, CA 94305

Dr. R. Lohsen  
Los Alamos National Laboratory  
P. O. Box 1663  
Los Alamos, NM 87545

Dr. M. Loring  
Oak Ridge National Laboratory  
P.O. Box Y  
Mail Stop 3  
Building 9201-2  
Oak Ridge, TN 37830

Dr. D. D. Lowenthal  
Spectra Technology  
2755 Northup Way  
Bellevue, WA 98004

Dr. A. Luccio  
Brookhaven National Laboratory  
Accelerator Dept.  
Upton, NY 11973

Dr. A. Lumpkin  
Los Alamos National Laboratory  
P. O. Box 1663  
Los Alamos, NM 87545

Dr. Phil Mace  
W. J. Shafer Assoc., Inc.  
1901 N. Fort Myer Drive  
Arlington, VA 22209

Dr. John Madey  
S.P.R.C.  
Physics Department  
Stanford University  
Stanford, CA 94305

Dr. Siva A. Mani  
Science Applications Intl. Corp.  
1040 Waltham Street  
Lexington, MA 02173-8027

Dr. J. Mark  
Lawrence Livermore National Lab.  
Attn: L-477  
P. O. Box 808  
Livermore, CA 94550

Dr. T. C. Marshall  
Applied Physics Department  
Columbia University  
New York, NY 10027

Dr. W. E. Martin  
L-436  
Lawrence Livermore National Lab.  
P. O. Box 808  
Livermore, CA 94550

Dr. Xavier K. Maruyama  
Dept. of Physics  
Naval Postgraduate School  
Monterey, CA 93943

Dr. Neville Marzwell  
Jet Propulsion Lab.  
MS 198-330  
4800 Oak Grove Drive  
Pasadena, CA 91109

Dr. A. Maschke  
TRW  
Mail Stop 01-1010  
1 Space Park  
Redondo Beach CA 90278

Dr. J. Masud  
Columbia University  
New York, NY 10027

Dr. Joseph Mathew  
Sachs/Freeman Associate  
Landover, MD

Dr. K. Matsuda  
GA Technologies Inc.  
P.O. Box 85608  
San Diego, CA 92138

Dr. John McAdoo  
Mission Research Corporation  
5503 Cherokee Ave., Suite 201  
Alexandria, Va 22312

Dr. D. B. McDermott  
Electrical Engineering Dept.  
University of California  
Los Angeles, CA 90024

Dr. J. K. McIver  
Dept. of Physics & Astronomy  
Univ. of New Mexico  
800 Yale Blvd. NE  
Albuquerque, NM 87131

Dr. C. McKinstrie  
MS B258  
P.O. Box 1663  
Los Alamos, NM 87545

Col J. F. McNulty  
Ground Based Laser Proj. Office  
DASD-H-F  
White Sands Missile Range, NM 88002-1198

Dr. B. McVey  
Los Alamos National Laboratory  
P. O. Box 1663  
Los Alamos, NM 87545

Dr. John Meson  
DARPA  
1400 Wilson Boulevard  
Arlington, VA 22209

Thomas Meyer  
ARPA/STO  
1400 Wilson Boulevard  
Arlington, VA 22209

Dr. F. E. Mills  
Fermilab  
P.O., Box 500  
Batavia, IL 60510

Dr. D. R. Mize  
Hughes Research Laboratory  
3011 Malibu Canyon Road  
Malibu, CA 90265

Dr. Mel Month  
Brookhaven National Laboratories  
Associated Universities, Inc.  
Upton, L.I., NY 11973

Dr. B. N. Moore  
Austin Research Assoc.  
1901 Rutland Dr.  
Austin, TX 78758

Dr. Gerald T. Moore  
University of New Mexico  
Albuquerque, NM 87131

Dr. Warren Mori  
1-130 Knudsen Hall  
U.C.L.A.  
Los Angeles, CA 90024

Dr. Philip Morton  
Stanford Linear Accelerator Center  
P.O. Box 4349  
Stanford, CA 94305

Dr. Jesper Munch  
TRW  
One Space Park  
Redondo Beach, CA 90278

Dr. James S. Murphy  
National Synchrotron Light Source  
Brookhaven National Laboratory  
Upton, NY 11975

Dr. Vloděk Nakonieczny  
P. O. Box 16325  
Knoxville, TN 37996-4900

Dr. J. Nation  
Cornell University  
Ithaca, NY 14850

Dr. R. Neighbours  
Physics Department  
Naval Postgraduate School  
Monterey, CA 93943

Dr. George Neil  
TRW  
One Space Park  
Redondo Beach, CA 90278

Dr. Kelvin Neil  
Lawrence Livermore National Lab.  
Code L-321, P.O. Box 808  
Livermore, CA 94550

Dr. W. M. Nevins  
L-639  
Lawrence Livermore National Laboratory  
P. O. Box 808  
Livermore, CA 94550

Dr. Brian Newnam  
MSJ 564  
Los Alamos National Scientific Lab.  
P.O. Box 1663  
Los Alamos, NM 87545

Dr. W. Nexsen  
Lawrence Livermore National Laboratory  
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Livermore, CA 94550

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TRW  
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Redondo Beach, CA 90278

Dr. T. Orzechowski  
L-436  
Lawrence Livermore National Lab.  
P. O. Box 808  
Livermore, CA 94550

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Department of Physics  
University of Maryland  
College Park, MD 20742

OUSDRE (R&AT)  
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Dr. A. J. Palmer  
Hughes Research Laboratory  
3011 Malibu Canyon Road  
Malibu, CA 90265

Dr. Robert B. Palmer  
Brookhaven National Laboratories  
Associated Universities, Inc.  
Upton, L.I., NY 11973

Dr. J. Palmer  
Hughes Research Laboratory  
Malibu, CA 90265

Dr. Richard H. Pantell  
Stanford University  
Stanford, CA 94305

Dr. Dennis Papadopoulos  
Astronomy Department  
University of Maryland  
College Park, Md. 20742

Dr. P. Parks  
GA Technologies  
P.O. Box 85608  
San Diego, Ca 92138

Dr. John A. Pasour  
Mission Research Laboratory  
5503 Cherokee Avenue  
Alexandria, VA

Dr. C. K. N. Patel  
Bell Laboratories  
Murray Hill, NJ 07974

Dr. Richard M. Patrick  
AVCO Everett Research Lab., Inc.  
2385 Revere Beach Parkway  
Everett, MA 02149

Dr. Claudio Pellegrini  
Brookhaven National Laboratory  
Associated Universities, Inc.  
Upton, L.I., NY 11973

Dr. Samuel Penner  
Center for Radiation Research  
National Bureau of Standards  
Gaithersburg, MD 20899

Dr. D. E. Pershing  
Mission Research Corporation  
5503 Cherokee Avenue  
Alexandria, VA 22312

Dr. J. M. Peterson  
Lawrence Berkeley Laboratory  
University of California, Berkeley  
Berkeley, CA 94720

Dr. M. Piestrup  
Adelphi Technology  
13800 Skyline Blvd. No. 2  
Woodside, CA 94062 CA 94305

Dr. Alan Pike  
DARPA  
1400 Wilson Boulevard  
Arlington, VA 22209

Dr. Hersch Pilloff  
Code 421  
Office of Naval Research  
Arlington, VA 22217

Dr. A. L. Pindroh  
Spectra Technology  
2755 Northup Way  
Bellevue, WA 98004

Dr. D. J. Pistoiresi  
Boeing Aerospace Company  
P. O. Box 3999  
Seattle, WA 98124-2499

Dr. Peter Politzer  
General Atomic Tech., Rm. 13/260  
P. O. Box 85608  
San Diego, CA 92138

Dr. S. E. Poor  
Lawrence Livermore National Laboratory  
P. O. Box 808  
Livermore, CA 94550

Prof. M. Porkolab  
NW 36-213  
Mass. Institute of Technology  
Cambridge, MA 02139

Dr. R. V. Pound  
Physics Department  
Harvard University  
Cambridge, MA 02138

Mr. J. E. Powell  
Sandia National Laboratories  
ORG. 1231, P.O. Box 5800  
Albuquerque, NM 87185

Dr. Mark A. Prelas  
Nuclear Engineering  
Univ. of Missouri-Columbia  
1033 Engineering  
Columbia, Missouri 65211

Dr. Donald Prosnitz  
Lawrence Livermore National Lab.  
Attn: L-470  
P. O. Box 808  
Livermore, CA 94550

Dr. D. C. Quimby  
Spectra Technology  
2755 Northup Way  
Bellevue, WA 98004

Dr. Paul Rabinowitz  
Xerox Research and Eng. Comp.  
P. O. Box 45  
Linden, NJ 07036

Dr. G. Ramian  
Quantum Institute  
University of California  
Santa Barbara, CA 93106

Dr. L. Ranjun  
Dept. of Physics  
University of Cal. at Irvine  
Irvine, CA 92717

Dr. L. L. Reginato  
Lawrence Livermore National Laboratory  
P. O. Box 808  
Livermore, CA 94550

Dr. M. B. Reid  
Dept. of Electrical Engineering  
Stanford University  
Stanford, CA 94305

Dr. D. A. Reilly  
AVCO Everett Research Lab.  
Everett, MA 02149

Dr. M. Reiser  
University of Maryland  
Department of Physics  
College Park, MD 20742

Dr. Bruce A. Richman  
High Energy Physics Lab.  
Stanford University  
Stanford, CA 94305

Dr. S. Ride  
Johnson Space Center  
Houston, TX 77058

Dr. C. W. Roberson  
Code 412  
Office of Naval Research  
800 N. Quincy Street  
Arlington, VA 22217

Dr. B. Robinson  
Boeing Aerospace Company  
P.O. Box 3999  
Seattle, WA 98124

Dr. K. Robinson  
Spectra Technology  
2755 Northup Way  
Bellevue, WA 98004

Dr. D. Rogers  
Lawrence Livermore National Laboratory  
P. O. Box 808  
Livermore, CA 94550

Dr. H. Romero  
ECE Department  
University of Wisconsin  
Madison, WI 53706

Dr. Jake Romero  
Boeing Aerospace Company  
P. O. Box 3999  
Seattle, WA 98124-2499

Dr. T. Romesser  
TRW, Inc.  
One Space Park  
Redondo Beach, Ca 90278

Dr. Marshall N. Rosenbluth  
Institute for Fusion Studies  
The Univ. of Texas at Austin  
Austin, TX 78712

Dr. J. B. Rosenzweig  
The Inst. for Accelerator Physics  
Department of Physics  
University of Wisconsin-Madison  
Madison, WI 53706

Dr. J. Ross  
Spectra Technology  
2755 Northup Way  
Bellevue, WA 98004

Dr. N. Rostoker  
University of California  
Department of Physics  
Irvine, CA 92717

Dr. G. A. Saenz  
Hughes Research Laboratory  
3011 Malibu Canyon Road  
Malibu, CA 90265

Dr. Antonio Sanchez  
Lincoln Laboratory  
Mass. Institute of Tech.  
Room B213  
P. O. Box 73  
Lexington, MA 02173

Dr. Aldric Saucier  
BMD-PO  
Ballistic Missile Defense  
Program Office  
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Arlington, VA 22215

Dr. A. Saxman  
Los Alamos National Scientific Lab.  
P. O. Box 1663, MSE523  
Los Alamos, NM 87545

Dr. J. Scharer  
ECE Dept.  
Univ. of Wisconsin  
Madison, WI 53706

Dr. E. T. Scharlemann  
L626  
Lawrence Livermore National Laboratory  
P. O. Box 808  
Livermore, CA 94550

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Dept. of Electrical Engineering  
Columbia University  
New York, NY 10027

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AFOSR  
Bolling AFB  
Washington, D.C. 20332

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Stevens Institute of Technology  
Physics Department  
Hoboken, NJ 07030

Dr. M. J. Schmitt  
Los Alamos National Laboratory  
P. O. Box 1663  
Los Alamos, NM 87545

Dr. Stanley Schneider  
Rotodyne Corporation  
26628 Fond Du Lac Road  
Palos Verdes Peninsula, CA 90274

Dr. N. Schoen  
TRW DSSG  
One Space Park  
Redondo Beach, CA 90278

Dr. M. L. Scott  
Los Alamos National Laboratory  
P. O. Box 1663  
Los Alamos, NM 87545

Dr. Richard L. Schriever (DP-23)  
Director, Office of Inertial Fusion  
U. S. Department of Energy  
Washington, D.C. 20545

Dr. R. W. Schumacher  
Hughes Research Laboratories  
3011 Malibu Canyon Road  
Malibu, CA 09265

Dr. H. Schwettmann  
Phys. Dept. & High Energy  
Physics Laboratory  
Stanford University  
Stanford, CA 94305

Dr. Marlan O. Scully  
Dept. of Physics & Astronomy  
Univ. of New Mexico  
800 Yale Blvd. NE  
Albuquerque, NM 87131

Dr. S. B. Segall  
KMS Fusion  
3941 Research Park Dr.  
P.O. Box 1567  
Ann Arbor, MI 48106

Dr. Robert Sepucha  
DARPA  
1400 Wilson Boulevard  
Arlington, VA 22209

Prof. P. Serafim  
Northeastern University  
Boston, MA 02115

Dr. A. M. Sessler  
Lawrence Berkeley Laboratory  
University of California  
1 Cyclotron Road  
Berkeley, CA 94720

Dr. W. Sharp  
L-626  
Lawrence Livermore National Laboratory  
P. O. Box 808  
Livermore, CA 94550

Dr. Earl D. Shaw  
Bell Laboratories  
600 Mountain Avenue  
Murray Hill, NJ 07974

Dr. J. P. Sheerim  
KMS Fusion  
P.O. Box 1567  
Ann Arbor, MI 48106

Dr. R. Shefer  
Science Research Laboratory  
15 Ward Street  
Somerville, MA 02143

Dr. R. L. Sheffield  
Los Alamos National Laboratory  
P.O. Box 1663  
Los Alamos, NM 87545

Dr. Shemwall  
Spectra Technology  
2755 Northup Way  
Bellevue, WA 98004

Dr. Shen Shey  
DARPA/DEO  
1400 Wilson Boulevard  
Arlington, VA 22209

Dr. Chun-Ching Shih  
TRW, Building R-1  
One Space Park  
Redondo Beach, CA 90278

Dr. D. Shoffstall  
Boeing Aerospace Company  
P.O. Box 3999  
Seattle, WA 98124

Dr. I. Shokair  
SNLA, Org. 1271  
Albuquerque, NM 87185

Dr. J. S. Silverstein  
Harry Diamond Laboratories  
2800 Powder Mill Road.  
Adelphi, MD 20783

Dr. Jack Slater  
Spectra Technology  
2755 Northup Way  
Bellevue, WA 98004

Dr. Kenneth Smith  
Physical Dynamics, Inc.  
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Lawrence Berkeley Laboratory  
University of California  
1 Cyclotron Road  
Berkeley, CA 94720

Dr. Stephen J. Smith  
JILA  
Boulder, CO 80302

Dr. T. Smith  
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Stanford, CA 94305

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Senior Technical Advisor  
Office of Energy Research  
U. S. Department of Energy  
Washington, D.C. 20585

Dr. J. Z. Soln (22300)  
Harry Diamond Laboratories  
2800 Powder Mill Road  
Adelphi, MD 20783

Dr. G. Spalek  
Los Alamos National Laboratory  
P. O. Box 1663  
Los Alamos, NM 87545

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STI  
2755 Northup Way  
Bellevue, WA 98004

Dr. A. Stern  
Quantum Inst. and Dept. of Physics  
University of California  
Santa Barbara, CA 93106

Dr. Efrem J. Sternbach  
Lawrence Berkeley Laboratory  
University of California, Berkeley  
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Department of Physics  
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3011 Malibu Canyon Road  
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ER 224, GTN  
Department of Energy  
Washington, D.C. 20545

Dr. Abraham Szoke  
ML/L-470  
Lawrence Livermore Natl. Lab.  
P.O. Box 808  
Livermore, CA 94550

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Dept. of Phys. & High Energy Lab.  
Stanford University  
Stanford, CA 94305

Dr. T. Tajima  
IFS  
Univ. of Texas  
Austin, TX 78712

Dr. H. Takeda  
Los Alamos National Laboratory  
P. O. Box 1663  
Los Alamos, NM 87545

Dr. J. J. Tancredi  
Hughes Aircraft Co.  
Electron Dynamics Division  
3100 West Lomita Blvd.  
Torrance, CA 90509

Dr. S. C. Tasker  
Dept. of Phys. & Res. Lab. of Electronics  
Mass. Institute of Technology  
Cambridge, MA 02139

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AVCO Everett Research Lab.  
2385 Revere Beach Parkway  
Everett, MA 02149

Dr. R. Temkin (2 copies)  
Mass. Institute of Technology  
Plasma Fusion Center  
Cambridge, MA 02139

Dr. L. Thode  
Los Alamos National Laboratory  
P. O. Box 1663  
Los Alamos, NM 87545

Dr. Keith Thomassen, L-637  
Lawrence Livermore National Laboratory  
P. O. Box 808  
Livermore, CA 94550

Dr. Harold Thompson  
TRW, Inc.  
R1/2120  
One Space Park  
Redondo Beach, Ca 90278

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Physics Department  
Vanderbilt University  
Nashville, TN 37240

Dr. Kang Tsang  
Science Applications Intl. Corp.  
10260 Campus Point Drive  
San Diego, CA 92121

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Boeing Aerospace Company  
P.O. Box 3999  
Seattle, WA 98124

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White Oak Lab.  
Silver Spring, MD 20903-5000

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TRW, Inc.  
One Space Park  
Redondo Beach, Ca 90278

Under Secretary of Defense (R&E)  
Office of the Secretary of Defense  
Room 3E1006, The Pentagon  
Washington, D.C. 20301

Dr. L. Vahala  
Physics Dept.  
College of William & Mary  
Williamsburg, VA 23185

Dr. A. Valla  
Spectra Technology  
2755 Northup Way  
Bellevue, WA 98004

Dr. A. Vetter  
Boeing Aerospace Company  
P.O. Box 3999  
Seattle, WA 98124

Dr. A. A. Vetter  
Spectra Technology  
2755 Northup Way  
Bellevue, WA 98004

Dr. G. Vignola  
Brookhaven National Laboratories  
Associated Universities, Inc.  
Upton, L.I., NY 11973

Dr. S. A. Von Laven  
KMS Fusion Inc.  
Ann Arbor, MI 48106

Dr. John E. Walsh  
Wilder Laboratory  
Department of Physics (HB 6127)  
Dartmouth College  
Hanover NH 03755

Dr. W. M. Walsh, Jr.  
Bell Laboratories  
600 Mountain Avenue  
Room 1-D 332  
Murray Hill, NJ 07974

Dr. Jiunn-Ming Wang  
Brookhaven National Laboratories  
Associated Universities, Inc.  
Upton, L.I., NY 11973

Dr. Ming Chang Wang  
Lab for Plasma Fusion  
University of Maryland  
College Park, MD 20742

Dr. T-S. Wang  
Los Alamos National Laboratory  
P. O. Box 1663  
Los Alamos, NM 87545

Dr. J. F. Ward  
University of Michigan  
Ann Arbor, MI 48109

Dr. E. Warden  
Code PDE 106-3113  
Naval Electronics Systems Command  
Washington, DC 20363

Dr. Roger W. Warren  
Los Alamos National Scientific Lab.  
P.O. Box 1663  
Los Alamos, NM 87545

Dr. J. Watson  
Los Alamos National Laboratory  
P. O. Box 1663  
Los Alamos, NM 87545

Dr. B. Weber  
Harry Diamond Laboratories  
2800 Powder Mill Road  
Adelphi, MD 20783

Dr. Lee Webster  
BMD/ATC  
Box 1500  
Huntsville, AL 35807

Dr. J. T. Weir  
Lawrence Livermore National Laboratory  
P. O. Box 808  
Livermore, CA 94550

Dr. R. Whitefield  
15260 Dickens Ave.  
San Jose, CA 95124

Ms. Bettie Wilcox  
Lawrence Livermore National Lab.  
ATTN: Tech. Info. Dept. L-3  
P.O. Box 808  
Livermore, CA 94550

Dr. Mark Wilson  
National Bureau of Standards  
Bldg. 245, Rm. B-119  
Gaithersburg, MD 20899

Dr. H. Winick  
Stanford Synch Rad. Lab.  
SLAC Bin 69  
P.O. Box 44349  
Stanford, CA 94550

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Berkeley Research Associates  
P.O. Box 241  
Berkeley, CA 94701

Dr. Jack Wong (L-71)  
Lawrence Livermore National Lab.  
P. O. Box 808  
Livermore, CA 94550

Dr. Thomas P. Wright  
Sandia National Laboratories  
ORG. 1231, P.O. Box 5800  
Albuquerque, NM 87185

Dr. J. Wurtele  
M.I.T.  
NW 16-234  
Plasma Fusion Center  
Cambridge, MA 02139

Dr. Ming Xie  
Dept. of Physics  
Stanford University  
Stanford, CA 94305

Dr. Yi-Ton Yan  
MS-B259  
Los Alamos National Lab.  
Los Alamos, NM 87545

Dr. T. P. Yang (2 copies)  
TRW  
1 Space Park  
Redondo Beach, CA 90278

Dr. A. Yariv  
California Institute of Tech.  
Pasadena, CA 91125

Dr. F. G. Yee  
Columbia University  
New York, NY 10027

Dr. J. Yeh  
Allied Corporation  
31717 La Tienda Dr.  
Westlake Village, CA 91362

Dr. A. Yeremian  
Boeing Aerospace Company  
P.O. Box 3999  
Seattle, WA 98124

Dr. Barbara Yoou  
R & D Associates  
1401 Wilson Blvd., Suite 500  
Arlington, VA 22209

Dr. Li Hua Yu  
725B, NSLS  
Brookhaven National Laboratory  
Upton, NY 11973

Dr. Simon S. Yu  
Lawrence Livermore National Laboratory  
P. O. Box 808  
Livermore, CA 94550

Dr. Mark Zedikev  
103 S. Goodwin  
Urbana, IL 61801

Dr. M. S. Zisman  
Lawrence Berkeley Laboratory  
University of California, Berkeley  
Berkeley, CA 94720

Dr. J. Zumdieck  
Spectra Technology  
2755 Northup Way  
Bellevue, WA 98004